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INVESTIGATION OF SOME MAGNETIC PROPERTIES OF Fe-Al ALLOYS

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ABSTRACT

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This work presents the results of a comprehensive investigation of the magnetic quantities I_s, H_c, χ_0 and λ_s in quenched and annealed alloys containing from 7.1 to 32.2 atomic percent of Al. The analysis of the results based on theory (refs. 1, 2 and 3) is presented. In addition, a qualitative evaluation is made of the internal stresses and the parameter "p" which is contained in the Kondorskiy-Kersten relationship for H_c.

Author

Samples, Heat Treatment, and Methods of Taking Measurements

The samples were prepared from Armco iron and electrolytic aluminum "00". The saturation intensity of magnetization I_s, the coersive force H_c and the saturation magnetostriction λ_s were measured by using rod samples (l = 160 - 170 mm, $\varnothing$ = 4 mm), while the initial permeability χ_0 was measured by using toroids (d_1 = 25 mm, d_2 = 20 mm, δ = 10 mm). After preparation, the samples were

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*Numbers given in the margin indicate the pagination in the original foreign text.

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annealed in rough exhaust at t = 900°C for a period of 10 hours and were cooled, together with the furnace. As a result the alloys, whose composition approximates Fe_3Al, were partially homogenized and assumed the ordered state. The second heat treatment consisted of annealing the samples for a period of 1 hour at t = 900°C, cooling with the furnace to 800°C and quenching in water. λ_s was measured by means of wire strain gages (ref. 4), while I_s, H_c and χ_0 were measured by the ballistic method. The relative measurement error was 3 to 4 percent.

Results of Measurements and Discussion

According to Becker (ref. 2), when we have an isotropic distribution of internal stresses, the following condition is satisfied in the material:

$$\chi_0 = \frac{2}{9}\frac{I_s^2}{\lambda_s}\left(\overline{\frac{1}{\sigma_i}}\right). \tag{1}$$

When the fluctuations of the internal stresses $\Delta\sigma_i$ are of the same order as σ_i, then according to Kondorskiy-Kersten (refs. 3 and 4)

$$H_c = p\,\frac{\lambda_s \sigma_i}{I_s}. \tag{2}$$

Eliminating σ_i, we have

$$H_c = \frac{2}{9}\,p\,\frac{I_s}{\chi_0}, \tag{3}$$

where the parameter "p" may not be greater than 3/2 oersted/gauss.

Relationships (1) and (3) were used to evaluate the internal stresses and to determine the parameter "p".

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First we consider λ_s, H_c and I_s as a function of the percentage of Al and /4
of the heat treatment. In annealed alloys with compositions approximating Fe_3Al, H_c and λ_s are about twice as large as in quenched samples (figs. 1 and 2).

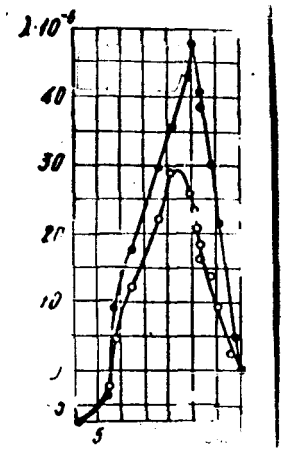
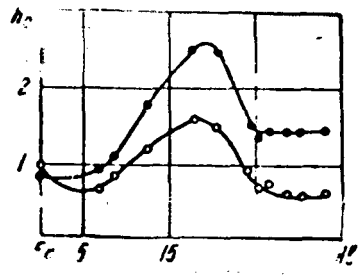


Figure 1



● = quenching
o = annealing

Figure 2

The variation in I_s of the alloys with different heat treatment is rather insignificant, and only for Fe_3Al does annealing increase I_s by 5 percent (ref. 5). The fact that in all quenched alloys H_c is smaller than in annealed samples is apparently explained by the decrease in $\Delta\sigma_i$. The alloy containing 20.6 atomic percent Al has the maximum H_c. According to references 6 and 7, it contains the most heterogeneous structure with two phases present: α- Fe and Fe_3Al. This is also confirmed by the variation in χ_0 (percent Al), which has a minimum value for the alloy of this composition (fig. 3). For alloys containing less than 20.6 atomic percent Al, quenching leads to a decrease in the value of χ_0, while for alloys approximating Fe_3Al in composition, it produces an increase in the value of χ_0, although in this case there is a slight increase in σ_i.

Since I_s varies little with various heat treatments, it follows from (1) that the decrease in λ_s during the quenching of these alloys is more pronounced

than the increase in σ_i. This is confirmed by the results of similar investigations at t = -196°C, when the difference in the values of χ_0 for quenched and annealed alloys increases. The same is observed for λ_s (ref. 5). We note that this is valid for temperatures when the process for the ordered distribution of Al and Fe atoms is practically absent.

As was to be expected, the evaluation of σ_i on the basis of (1) shows that in quenched alloys they are greater than in annealed alloys (fig. 4).

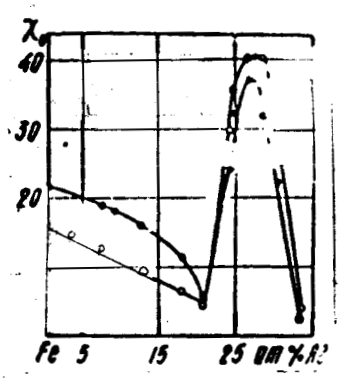


Figure 3

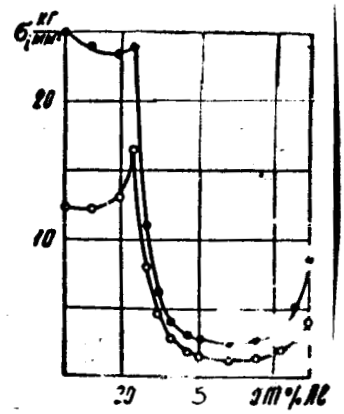


Figure 4

● = quenching
○ = annealing

Of greatest interest is the evaluation of σ_i for alloys in the transition region from the lattice α- Fe to the lattice Fe_3Al (20 - 22 atomic percent Al). Here, as pointed out, we have the maximum heterogeneity in the structure of the alloys, because, according to the Kondorskiy-Kersten theory (refs. 3 and 4), H_c is proportional to $\Delta\sigma_i$. For the alloys investigated, the maxima of H_c and $\Delta\sigma_i$ occur in the same composition (figs. 2 and 4), which is a very good confirmation of the theory.

The parameter "p" was computed from relationship (3). As predicted by theory, its magnitude does not exceed the value 0.26 oersted/gauss, and the

functions p(percent Al) and $\varkappa_0$(percent Al) resembles each other a great deal, which can be explained by the very sharp variation in $\varkappa_0$ (compared with H_c and I_s). /5

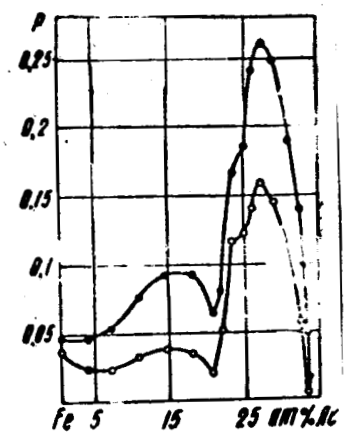


Figure 5

Conclusions

1. It has been shown that for ferromagnetic alloys of the system Fe-Al for different heat treatments, H_c is directly proportional to λ_s and inversely proportional to $\varkappa_0$.

2. The qualitative evaluation of σ_i has shown that for quenched and annealed alloys approximating Fe_3Al in composition, they (as well as H_c) vary little and the maxima of $\Delta\sigma_i$ and H_c occur in alloys of identical composition.

3. The value of the parameter "p" in annealed alloys is greater than in quenched allows and does not exceed 0.26 oersteds/gauss.

The results which have been obtained are in agreement with theory (refs. 1, 2 and 3).

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